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Massive star formation in Wolf-Rayet galaxies*

I. Optical and NIR photometric results

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ABSTRACT

Aims. We have performed a comprehensive multiwavelength analysis of a sample of 20 starburst galaxies that show the presence of a substantial population of massive stars. The main aims are the study of the massive star formation and stellar populations in these galaxies, and the role that interactions with or between dwarf galaxies and/or low surface companion objects have in triggering the bursts. In this series of papers, we present our new optical and near-infrared photometric and spectroscopic observations, and complete with data at other wavelengths (X-ray, far-infrared, and radio) available in the literature. In this paper, the first in the series, we analyze the morphology, stellar population age, and star-formation rate of each system.

Methods. We completed new deep optical and *NIR* broad-band images, as well as the new continuum-subtracted Hα maps, of our sample of Wolf-Rayet galaxies. We analyze the morphology of each system and its surroundings and quantify the photometric properties of all important objects. All data were corrected for both extinction and nebular emission using our spectroscopic data. The age of the most recent star-formation burst is estimated and compared with the age of the underlying older low-luminosity population. The Hα-based star-formation rate, number of O7V equivalent stars, mass of ionized gas, and mass of the ionizing star cluster are also derived.

Results. We found interaction features in many (15 up to 20) of the analyzed objects, which were extremely evident in the majority. We checked that the correction for nebular emission to the broad-band filter fluxes is important in compact objects and/or with intense nebular emission to obtain realistic colors and compare with the predictions of evolutionary synthesis models. The estimate of the age of the most recent star-formation burst is derived consistently. In general, the Hα-based star formation rate agrees with the estimates given by independent multiwavelength methods. With respect to the results found in individual objects, we remark the strong Hα emission found in IRAS 08208+2816, UM 420, and SBS 0948+532, the detection of a double-nucleus in SBS 0926+606A, a possible galactic wind in Tol 9, and one (two?) nearby dwarf star-forming galaxies surrounding Tol 1457-437.

Key words. galaxies: starburst — galaxies: interactions — galaxies: stellar populations — galaxies: optical/*NIR* & Hα photometry — stars: Wolf-Rayet

1. Introduction

1.1. The nature of Wolf-Rayet galaxies

Wolf–Rayet (WR) galaxies are a subset of emission-line and H II galaxies, whose integrated spectra show broad emission features attributed to the presence of WR stars, indicating that a substantial population of this type of massive star exists in the ionized cluster(s) of the star-formation bursts. The most massive O stars ($M \geq 35\ M_\odot$ for $Z_\odot$) become WR stars around 2 and 3 Myr after their birth, spending only some few hundreds of thousands of years ($t_{WR} \leq 10^6$ yr) in this phase (Maeder & Meynet 1994) until they explode as Type Ib/Ic supernovae (van der Hucht 2001). The minimum stellar mass that an O star needs to reach the WR phase and its duration is dependent on metallicity. There are two important broad features that reveal the presence of WR stars: the so-called blue WR bump (between 4650–4690 Å) and the red WR bump (basically formed by the C IV λ5808 emission line). The broad, stellar, He II λ4686 is the main feature of the blue WR bump. The narrow, nebular He II λ4686 is usually associated with the presence of these massive stars, although it is rarely strong and its origin remains controversial (Garnett et al. 1991; Garnett 2004).

The detection of WR features in the spectrum of a starburst galaxy constrains the parameters that characterize the star-formation burst: the initial mass funtion must be extended to higher masses; the WR/O ratio is relatively large and the burst must therefore be short; and the time elapsed since the last starburst episode occurred must be less than a few Myr. Therefore, WR galaxies offer the op-

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* Based on observations made with NOT (Nordic Optical Telescope) and INT (Isaac Newton Telescope) operated on the island of La Palma jointly by Denmark, Finland, Iceland, Norway and Sweden (NOT) or the Isaac Newton Group (INT) in the Spanish Observatorio del Roque de Los Muchachos of the Instituto de Astrofísica de Canarias. Based on observations made at the Centro Astronómico Hispano Alemán (CAHA) at Calar Alto, operated by the Max-Planck Institut für Astronomie and the Instituto de Astrofísica de Andalucía (CSIC).

portunity to study an approximately coeval sample of very young starbursts (Schaerer & Vacca 1998).

The blue compact dwarf galaxy He 2-10 was the first object in which WR features were detected (Allen, Wright & Goss 1976). Osterbrock & Cohen (1982) and Conti (1991) introduced the concept of a WR galaxy, to be *a galaxy whose integrated spectrum has detectable WR broad stellar emission lines emitted by unresolved stellar clusters*. Kunth & Joubert (1985) performed the first systematic search for WR features in emission-line galaxies: in their sample of 45 extragalactic H II regions they classified 17 as WR galaxies. Kunth & Schild (1986) and Dinerstein & Shields (1986) reported the first detections of the red WR bump. Conti (1991) compiled the first WR catalogue, including 37 objects. Vacca & Conti (1992) developed the first quantitative scheme to estimate WR populations in starbursts using new quality data. The majority of detections of WR features have however been accidental, and have occurred in studies that cover a wide range of topics, from the determination of the primordial He abundance (Kunth & Sargent 1983; Kunth & Joubert 1985; Izotov, Thuan, & Lipovetski 1994; Izotov et al. 1997; Izotov & Thuan 1999, 1998; Thuan, Izotov & Lipovetsky 1995), the nature of Seyfert galaxies (Heckman et al. 1997), and starbursts with strong galactic winds (Allen, Wright & Goss 1976). Guseva, Izotov & Thuan (2000) analyzed a sample of 39 objects with heavy element abundances ranging from $Z_\odot/50$ to $2Z_\odot$ and obtained global results for WR galaxies. Buckalew, Kobulnicky & Dufour (2005) compared the properties of young star clusters with and without WR stars.

The most recent catalogue of WR galaxies was compiled by Schaerer et al. (1999) and listed 139 members, although this number has since increased (Popescu & Hopp 2000; González-Delgado, Heckman & Leitherer 2001; Bergvall & Östlin 2002; Contini et al. 2002; Pindao et al. 2002; Lípari et al. 2003; Tran et al. 2003; Fernandes et al. 2004; Izotov et al. 2004; Pustilnik et al. 2004; Jamet et al. 2004; Thuan & Izotov 2005), and these galaxies have even been detected at high z (Villar-Martín et al. 2004). In a study of emission-line galaxies extracted from the Sloan Digital Sky Survey (York et al. 2000) WR features were identified in many star-forming galaxies (Kniazev et al. 2004; Zhang et al. 2007), increasing the number of known WR galaxies to more than 300.

Morphologically, WR galaxies constitute an inhomogeneous class of star-forming objects. They are detected in irregular galaxies, blue compact dwarf galaxies (BCDGs), spiral galaxies (or, more precisely, giant H II regions in the arms of spiral disks), luminous, merging IRAS galaxies, active galactic nuclei (AGNs), and Seyfert 2 and low-ionization nuclear emission-line regions (LINERs) galaxies. Quoting Schaerer et al. (1999), the minimum common property of all WR galaxies is *ongoing or recent star formation that has produced stars sufficiently massive to evolve to the WR stage*.

We note that the definition of WR galaxy is *dependent of the quality of the spectrum, and location and size of the aperture*. The term WR galaxy must therefore be used with caution. The presence of WR features in the spectrum of a starburst *does not* imply that WR stars are present at all locations, but only that a significant population of this type of massive star exits inside the galaxy. Depending on the distance of the object and size of the area analyzed, the region of concern may be a single extragalactic H II region with a few WR stars in a galaxy, a massive star cluster or the nucleus of a powerful starburst galaxy harbouring numerous massive stars (Schaerer et al. 1999). The precise locations of the WR stars usually remain unknown, apart from for the Local Group or other nearby galaxies. The width of the extraction aperture for which the spectrum is extracted can sometimes be too large and the weak WR features diluted by the continuun flux. Furthermore, a starburst galaxy with several star-forming bursts may only show WR features in one of them. Aperture effects and the slit position can therefore play an important role in the detection of WR features (Huang et al. 1999; López-Sánchez et al. 2004a,b; Buckalew, Kobulnicky & Dufour 2005; López-Sánchez, Esteban & García-Rojas 2006).

1.2. Aims of this paper series

In dwarf galaxies, starburst phenomena cannot be explained by the wave-density theory because of their low masses, and an alternative mechanism must operate. A proposed alternative mechanism for large-scale starburst formation is gas compression by shocks due to mass loss by means of galactic winds and the subsequent cooling of the medium (Thuan 1991; Hirashita 2000). Other authors however proposed galaxy interactions as a massive-star formation triggering mechanism (Sanders et al. 1988). Interactions appear to play a fundamental role triggering starbursts, both in spiral (Koribalski 1996; Kennicutt 1998), and dwarf and irregular galaxies. In these cases, interactions with nearby giant galaxies are unusual (Campos-Aguilar, Moles & Masegosa 1993; Telles & Terlevich 1995), but with low surface-brightness galaxies (Wilcots, Lehman & Miller 1996; Noeske et al. 2001) or H I clouds (Taylor et al. 1996; Thuan et al 1999; van Zee et al. 2001). Studying a sample of WR galaxies, Méndez (1999) performed an analysis of 13 objects extracted from the catalogue of Conti (1991), finding that 7 are clearly interacting and another 4 show features of interactions. For example, he found a bridge between two galaxies in Zw 0855+06 (Méndez et al. 1999a), prominent tidal tails in Mkn 8 (Esteban & Méndez 1999), star-formation activity induced by an H I cloud in Mkn 1094 (Méndez et al. 1999b) and an intermediate-age merger in Tol 35 (Méndez & Esteban 1999). For the first time, these facts enabled Méndez & Esteban (2000) to suggest that interactions with or between dwarf objects could be the main star-formation triggering mechanism in dwarf galaxies. These authors also noted that the interacting and/or merging nature of WR galaxies can be detected only when both deep, high-resolution images and spectra are available.

Subsequent works (Iglesias-Páramo & Vílchez 2001; Verdes-Montenegro et al. 2001, 2002; Tran et al. 2003) also found a relation between massive star formation and the presence of interaction signatures in this type of starburst. However, a systematic analysis of a significant sample of starburst galaxies containing WR stars was needed to derive more robust statistics and definitive results. We have therefore completed a detailed morphological, photometric, and spectroscopic study of 20 objects, the majority being extracted from the catalogue of WR galaxies published by Schaerer et al. (1999). This study combines deep

Table 1. Main data of the sample of 20 WR galaxies analyzed in this work.

Galaxy	R.A.(2000) ($h\ m\ s$)	Dec.(2000) ($^\circ\ '\ ''$)	$E_G(B-V)^a$	m_B^b	M_B^b	d^c (Mpc)	[O/H]^d (dex)	Type^e	Other names
NGC 1741	05 01 38.4	−04 15 25	0.051	13.59	−20.01	52.5	8.22	pec	HCG 31 AC, Mkn 1089, SBS 0459-043
Mkn 1087	04 49 44.4	+03 20 03	0.063	13.08	−22.14	110.6	8.57*	S0 pec	II Zw 23
Haro 15	00 48 35.9	−12 43 07	0.023	13.82	−20.87	86.6	8.37*	(R)SB0 pec?	Mkn 960
Mkn 1199	07 20 28.3	+33 32 21	0.054	12.98	−20.68	54.0	8.75*	Sc H II	SBS 0720+335
Mkn 5	06 42 15.5	+75 37 33	0.084	14.83	−15.57	12.0	8.07	I? H II	SBS 0635+756
IRAS 08208+2816	08 23 55.0	+28 06 14	0.032	15.10	−21.29	190.0	8.42*	Irr	...
IRAS 08339+6517	08 38 23.2	+65 07 15	0.092	12.94	−21.57	78.3	8.45*	Pec LIRG H II	...
POX 4	11 51 11.6	−20 36 02	0.039	14.56	−18.79	45.5	8.03	H II	IRAS 11485-2018
UM 420	02 20 54.5	+00 33 24	0.036	17.32	−19.55	237.1	7.95	Compact	SBS 0218+003
SBS 0926+606A	09 30 06.5	+60 26 52	0.031	16.45	−17.29	55.9	7.94	BCG, H II	...
SBS 0948+532	09 51 32.0	+52 59 36	0.013	17.93	−18.43	187.4	8.03	Sy	...
SBS 1054+365	10 57 47.0	+36 15 26	0.021	15.46	−14.06	8.0	8.00	NE	...
SBS 1211+540	12 14 02.5	+53 45 18	0.020	17.32	−13.27	13.1	7.65	BCG	...
SBS 1319+579	13 21 10.0	+57 39 41	0.014	15.32	−18.53	28.8	8.05*	H II	...
SBS 1415+437	14 17 01.7	+43 30 13	0.009	15.32	−14.52	9.3	7.58	BCG	...
III Zw 107	23 30 09.9	+25 31 58	0.060	14.36	−20.14	79.6	8.23	Im	IV Zw 153, IRAS 23276+2515
Tol 9	10 34 38.7	−28 35 00	0.065	13.92	−19.26	43.3	8.58	E4: H II	IRAS 10323-2819,ESO 435-42,Tol 1032-283
Tol 1457-262a	15 00 29.0	−26 26 49	0.158	14.44	−19.73	68.1	8.22*	H II	IRAS 14575-2615, ESO 513-IG11
Arp 252	09 44 58.6	−19 43 32	0.049	16.22	−19.35	129.8	8.50*	Gpair pec	ESO 566-7 + ESO 566-8
NGC 5253	13 39 55.9	−31 38 24	0.056	10.09	−17.92	4.0^f	8.28*	Im pec H II	Haro 10

[a] Value of the Galactic extinction (Schlegel et al. 1998).
[b] Corrected for Galactic and internal extinction.
[c] Except for NGC 5253, the distances were estimated from our optical spectra and correcting for Galactic Standard of Rest (see Paper II).
[d] Oxygen abundance, in units of 12+log(O/H), derived in this work for each galaxy (see Paper II). If several regions were analyzed in the same galaxy (indicated by a star), the highest oxygen abundance derived using T_e is shown.
[e] Morphological type as indicated by NED.
[f] Distance obtained by Karachentsev et al. (2004).

optical and near-infrared (*NIR*) broad-band and Hα imaging with optical spectroscopy (long-slit and echelle) data. Additional X-ray, far-infrared, and radio data were compiled from the literature. We performed a comprehensive and coherent study of all galaxies using the same reduction and analysis procedures and the same set of equations to determine their physical and chemical properties, with the emphasis of a global analysis of the sample. The main aims are to study the formation of massive stars in starburst galaxies and the role that interactions with or between dwarf galaxies and/or low surface brightness objects have in triggering bursts. The results of this deep analysis of local starbursts would also have an important impact on our knowledge about the galaxy evolution: galaxy interactions between dwarf objects should be more common at high redshifts, as hierarchical formation models of galaxies (i.e. Kauffmann & White 1993; Springer et al. 2005) predict.

1.3. Structure of the study

We analyze our sample of WR galaxies in the following way. In this paper (Paper I), we present the photometric results derived from the optical and near-infrared (*NIR*) broad-band and Hα images. The aims of the observations in broad-band filters are the following:

1. To analyze the stellar-component morphology of each galaxy, looking for signs of interactions (e.g. arcs, plumes, bridges, and tidal tails) and possible low-surface brightness companion objects. The identification and the localization of these features and external objects with respect to the main galaxies provides clues about their evolution, allowing us to suggest how the star-formation burst was triggered.
2. To perform aperture photometry of each galaxy and its different regions (star-forming knots and emission-free areas) to characterize the stellar population that dominates the bursts and the underlying low-luminosity component. The comparison of the colors with the predictions of population synthesis models permits us to estimate the age of the last star-formation burst.

We completed deep observations in narrow-band Hα filters to study the extension and properties of the ionized gas. The continuum-subtracted Hα images were used to:

1. Study the distribution of the ionized gas, and check the physical association of other surrounding star-forming objects with the main galaxy.
2. Estimate the Hα luminosity, which indicates the total number of ionized stars in each burst and in the galaxy, as well as the ionized gas mass and the star formation rate (SFR). The total mass of the ionizing cluster can also be estimated.
3. Calculate the Hα equivalent width, which is a powerful indicator of the age of the last star-formation burst.

In Sect. 2 we present our observations, some details of the data reduction processes, and some useful relations. A description of the galaxies, the deep optical maps obtained for each system, and the photometric results for all optical and *NIR* broad-band and Hα filters are presented in Sect. 3. Some results found in the photometric analysis of our galaxy sample and its summmary are discussed in Sect. 4.

In the second paper of this series (Paper II), we will present results derived by analyzing our intermediate-

Table 2. Journal of observations for broad-band optical filters. All exposure times are provided in seconds. Note that in some cases there are several observations per filter. Dates follow the format year/month/day.

Galaxy	*U*			*B*			*V*			*R*		
	Tel.	Date	T. exp	Tel.	Date	T. exp	Tel.	Date	T. exp	Tel.	Date	T. exp
HCG 31	NOT	02/10/23	3×300	NOT	02/10/23	3×300	NOT	02/10/23	4×300	INT	03/09/22	2×200
Mkn 1087	NOT[a]	97/02/06	3×300	NOT	03/01/20	3×300	2CAHA	00/12/19	3×1200	NOT	03/01/20	6×300
Mkn 1199	INT	05/11/19	3×300	2CAHA	04/11/07	3×300	2CAHA	00/12/19	5×400	2CAHA	04/11/07	3×300
	NOT	06/01/07	2×60	INT	05/11/19	3×300	NOT	06/01/07	3×60			
Mkn 5	NOT	04/01/20	3×300	NOT	04/01/20	3×300	NOT	04/01/20	3×300	NOT	05/04/05	3×300
Haro 15	INT	05/11/19	4×300	INT	05/11/19	3×300	2CAHA	00/12/19	3×1200	2CAHA	04/11/06	3×300
	NOT	06/01/07	2×60	NOT	06/01/07	2×60	NOT	06/01/07	2×60			
POX 4	NOT[a]	97/02/06	3×400	NOT[a]	97/02/06	3×300	NOT[a]	97/02/06	3×300	NOT	05/04/03	3×300
UM 420	INT	05/10/06	3×300	INT	05/10/06	3×300	INT	05/10/06	3×300	2CAHA	04/11/06	3×300
IRAS 08208+2816	NOT	04/01/20	3×300	NOT	04/01/20	3×300	NOT	04/01/20	3×300	NOT	05/04/05	3×300
							2CAHA	00/12/19	3×1200			
IRAS 08339+6517	NOT	05/04/03	3×300	NOT	05/04/03	3×300	NOT	04/03/20	2×300	NOT	04/03/20	3×300
SBS 0926+606A	NOT	04/01/20	3×300	NOT	04/01/20	3×300	NOT	04/01/20	3×300	2CAHA	04/11/07	3×300
SBS 0948+532	NOT	05/04/05	3×300	NOT	05/04/03	3×300	NOT	05/04/03	3×300	NOT	05/04/03	3×300
SBS 1054+365	NOT	04/01/20	3×300	NOT	04/01/20	3×300	NOT	04/01/20	3×300	...	...	...
							2CAHA	00/12/19	3×1200			
SBS 1211+540	NOT	05/04/04	3×300	NOT	05/04/04	3×300	NOT	05/04/04	3×300	NOT	05/04/04	3×300
SBS 1319+579	NOT	04/03/20	3×300	NOT	04/03/20	3×300	NOT	04/03/20	3×300	NOT	05/04/03	3×300
SBS 1415+437	NOT	05/04/03	3×300	NOT	05/04/03	3×300	NOT	05/04/03	3×300	NOT	05/04/03	3×300
III Zw 107	INT	05/10/06	3×300	2CAHA	04/11/07	3×300	2CAHA	04/11/07	3×300	INT	05/10/06	3×300
				INT	05/10/06	3×300						
Tol 9	NOT	05/04/05	3×300	NOT	05/04/05	3×300	2CAHA	00/12/19	3×1200	NOT	05/04/05	3×300
Tol 1457-262a	NOT	05/04/03	3×300	NOT	04/03/20	3×300	NOT	04/03/20	3×300	NOT	05/04/03	3×300
Arp 252	NOT	04/03/20	3×300	NOT	04/03/20	3×300	NOT	04/03/20	3×300	NOT	05/04/04	3×300
							2CAHA	00/12/19	3×1200			

[a] Images published by Méndez & Esteban (2000).

resolution spectroscopy. In the final paper (Paper III), we will compile the properties derived using data from other wavelengths and summarize the global analysis combining all available multiwavelength data. It is, so far, the most complete and exhaustive data set of this kind of galaxies, involving multiwavelength results and analyzed following the same procedures. We will discuss the significant role that interactions with or between dwarf galaxies play in the triggering of massive star formation in Wolf-Rayet galaxies.

2. Observations

Our photometric observations are classified into three types: broad-band optical imagery (standard Johnson filters in U, B, V, and R bands), narrow-band Hα and adjacent continuum imagery (narrow-band filters centered at the wavelength of the Hα emission line at the redshift of the galaxy), and broad-band *NIR* imagery (filters in J, H and Ks bands). We describe our observations, reduction, analysis procedures, and present the selection criteria of our sample of WR galaxies.

2.1. Selection criteria of the sample galaxies

Since we are interested in the analysis of the massive star population (Wolf-Rayet stars) in starburst galaxies, we considered the most recent catalogue of Wolf-Rayet galaxies (Schaerer et al. 1999) as a starting point. As we remarked in the introduction, the WR galaxy catalogue contains an inhomogeneous group of starbursting objects. Our analysis however is mainly focused in dwarf galaxies. Therefore, we did not consider either spirals galaxies or giant H II regions within them, and considered only dwarf objects, such as apparently isolated BCDGs and dwarf irregular galaxies that had peculiar morphologies in previous, shallower imaging. Finally, we chose a sample of dwarf WR galaxies that could be observed from the Northern Hemisphere. The only exception was NGC 5253, for which deep echelle spectrophotometry using 8.2m VLT was obtained (see López-Sánchez et al. 2007). We also chose two galaxies belonging to the Schaerer et al. (1999) catalogue that were classified as *suspected* WR galaxies (Mkn 1087 and Tol 9), to confirm the presence of massive stars within them. Finally, we also included the galaxy IRAS 08339+6517 because previous multiwavelength results suggested that the WR stars could still be present in its youngest star-forming bursts (see López-Sánchez et al. 2006).

The general properties of our galaxy sample are described in Table 1, where we provide the equatorial coordinates, Galactic extinction, apparent and absolute B-band magnitudes, distances (assuming a Hubble flow with H_0 = 75 km s^{-1} and q_0 = 0.5, and correcting for Galactic Standard of Rest using our spectroscopic data; see Paper II), oxygen abundances (derived from our spectroscopic data; see Paper II), morphological type (derived from NED), and other common names for each system.

2.2. Optical imagery

Images in optical wavelengths were obtained in several observing runs between the years 2000 and 2006, mainly using the 2.56m *Nordical Optical Telescope* (NOT) located at the *Roque de los Muchachos* Observatory (ORM, La Palma, Spain). However, some observations were completed at the 2.5m *Isaac Newton Telescope* (INT), located at the ORM, and in the 2.2m telescope of the *Centro Astronómico Hispano-Alemán* (CAHA) at *Calar*

Table 3. Log of our *NIR* observations, all completed at CST. Dates follow the format year/month/day.

	J		H		K_s	
Galaxy	Date	N×Exp.Time (s)	Date	N×Exp.Time (s)	Date	N×Exp.Time (s)
HCG 31	03/02/04	120×20	03/02/04	240×10	03/02/04	360×5
Mkn 1087	02/09/24	120×20	02/09/24	240×10	02/09/24	360×5
Haro 15	02/09/24	120×20	02/09/24	240×10	02/09/24	360×5
Mkn 1199	03/02/04	120×20	03/02/04	120×10	03/02/04	360×5
Pox 4	04/02/03	180×20	05/05/23	240×10	05/05/23	240×5
UM 420	04/02/02	240×20	04/02/03	360×10	04/02/03	240×5
IRAS 08208+2816	03/03/29	120×20	03/03/29	240×10	03/02/04	240×5
SBS 0926+606A	03/03/26	180×20	03/03/26	360×10	03/03/28	480×5
SBS 1054+365	03/03/28	120×20	03/03/28	360×10	03/03/28	360×5
SBS 1319+579	04/02/02	120×20	04/02/28	240×10	04/02/28	360×5
SBS 1415+437	03/03/26	180×20	03/03/28	360×10	03/03/29	240×5
Tol 9	04/02/03	180×20	04/02/03	360×10	05/04/24	240×5
Tol 1457-262a	04/04/18	120×20	04/04/18	240×10	04/04/19	240×5
Arp 252	04/02/01	180×20	04/02/01	240×10	...	...

Alto Observatory (Almería, Spain). In Table 2, the telescope, date, number of images, and exposure time for the broad-band optical observations of our galaxy sample are indicated. We observed 18 galaxies in *all* optical broad-band filters, SBS 1054+365 was observed in all filters apart from R-band, and only one galaxy (NGC 5253) was not observed for which we adopt data from NED. We also used the photometric data of Mkn 1087 (U-band) and POX 4 (U, B and V bands) given by Méndez (1999). The details of these observations are the following:

1. Observations at the 2.56m NOT. We completed three observing runs at this telescope: January-March 2004, April 2005, and April 2006. We also obtained data during three Spanish Service-Time nights (23 October 2002, 20 January 2003, and 7 January 2006). In all observations, the ALFOSC (*Andalucia Faint Object Spectrograph and Camera*) instrument was used in image mode, with a CCD Loral/Lesser detector 2048 × 2048 pixel array, pixel size of 15 μm. The spatial resolution was 0.19″ pixel^{-1}, and the field of view was 6.3' × 6.3'.
2. Observations at the 2.2m CAHA. Two observing runs were completed at this telescope, in December 2000 and November 2004, using the CAFOS (*Calar Alto Faint Object Spectrograph*) instrument in image mode. CAFOS was located at the Cassegrain focus of the telescope. Two different detectors were used: a CCD SITe detector with 2048 × 2048, a pixel size of 24 μm, and 0.53″ pixel^{-1} spatial resolution during the observations in December 2000, and a CCD LORAL detector with 2048 × 2048, a pixel size of 15 μm, and 0.33″ pixel^{-1} spatial resolution for observations in November 2004. Because of the physical size of the filters, only a circular disk with a diameter of 11' is not vignetted by this instrument.
3. Observations at the 2.5m INT were completed on 22 September 2003 and 6 October 2005, as well as 19 November 2005 (a Spanish Service-Time night under non-photometric conditions). We used the *Wide Field Camera* (WFC) that consists of 4 adjacent CCDs each an array of 2048 × 4096 pixels with a pixel size of 15 μm. Located in the primary focus of the telescope, it has a spatial resolution of 0.33″ pixel^{-1}, yielding a field of view of 11.2' × 22.4' in each chip. In our observations, only the central chip was analyzed.

The details of the reduction process and analysis of the optical images are described in Appendix A.

2.3. NIR *imagery*

All *NIR* observations with J, H and K_s filters were completed at the 1.5m Carlos Sánchez Telescope (CST), located at the Observatorio del Teide (Tenerife, Spain). We used the CAIN camera, which has a mosaic of 256 × 256 pixels sensitive in the 1–2.5 μm wavelength interval consisting of four independent chips of dimensions 128 × 128 pixels, each one controlling one quadrant of the camera. The physical size of each pixel is 40 μm, corresponding to 1″ pixel^{-1} in wide field mode. The total field of view was 4'×4'.

We acquired a sequence of exposures at slightly different positions to obtain a clean sky image, following the method described in López-Sánchez et al. (2004a). Table 3 shows the number of individual raw images obtained for each galaxy and filter as well as the date on which they were acquired.

We completed four observings runs at the telescope: September 2002, March 2003, February 2004, and April 2004. Additionally, we also observed on 4 February 2003 and 23 May 2005. Because of the upper limit in declination of the CST (65°), Mkn 5, and IRAS 08339+6517 were not observed. The starburst galaxy NGC 5253 was not observed because it is a southern object. Three galaxies (III Zw 107, SBS 0948+532 and SBS 1211+540) were not observed because of several technical problems and/or bad weather conditions. Therefore, only 14 galaxies of our sample were observed in *NIR* using CST, 13 of them using all filters (Arp 252 was not observed in K_s). For those objects, we did not acquire new *NIR* data, but used instead results given by the *Two Micron All Sky Survey* (2MASS, see Cutri et al. 2000; Jarrett et al. 2000) project. The details of the reduction process and analysis of the NIR images are described in Appendix B.

2.4. Hα *imagery*

Hα and adjacent continuum images were obtained during the same runs used for the observation of the broad-band images, and therefore using the same telescopes and instrumentation. We chose adequate narrow-band filters (with a FWHM of ∼50 Å) to detect the redshifted Hα

Table 4. Log of the Hα observations. Times are indicated in seconds. Dates follow the format year/month/day.

Galaxy	Telescope	Date	Hα Filter	Time	K	Hα cont. Filter	Time	K	seeing[a] ($''$)
HCG 31	2.2CAHA	04/11/06	667/8	4×300	1.44	683/9	1×300	1.37	1.1
Mkn 1087	2.2CAHA	04/11/06	674/7	4×300	1.21	727/16	2×300	1.23	1.3
Haro 15	2.2CAHA	04/11/06	667/8	3×300	1.65	683/9	1×300	1.73	1.5
Mkn 1199	2.2CAHA	00/12/20	667/8	3×600	1.03	613/12	3×600	1.00	2.2
Mkn 5	NOT	05/04/04	IAC-20	3×300	1.54	IAC-36	2×300	1.55	0.8
POX 4[b]	NOT	97/02/04	IAC-24	3×900	–	NOT-21	3×600	–	1.2
UM 420	2.2CAHA	04/11/06	696/15	3×300	1.26	667/8	1×300	1.30	1.0
IRAS 08208+2816	NOT	04/01/20	IAC-36	3×300	1.02	NOT-21	3×300	1.00	0.6
IRAS 08339+6517	NOT	04/03/20	IAC-19	3×300	1.25	IAC-20	2×300	1.26	0.6
SBS 0926+606A	2.2CAHA	04/11/07	667/8	3×300	1.12	683/9	1×300	1.10	1.4
SBS 0948+532	NOT	05/04/05	IAC-36	3×300	1.10	IAC-19	2×300	1.11	1.4
SBS 1054+365	NOT	04/01/20	NOT-21	4×300	1.06	–	–	–	–
	NOT	04/03/20	–	–	–	IAC-36	2×300	1.04	0.7
SBS 1211+540	NOT	05/04/04	IAC-20	3×300	1.16	IAC-36	2×300	1.19	0.6
SBS 1319+579	NOT	04/03/20	IAC-12	3×300	1.18	IAC-36	2×300	1.20	0.7
	NOT	05/04/03	IAC-12	4×300	1.15	IAC-36	2×300	1.14	0.8
SBS 1415+437	NOT	05/04/03	IAC-20	3×300	1.06	IAC-36	2×300	1.08	0.6
III Zw 107	2.2CAHA	04/11/06	667/8	3×300	1.03	683/9	1×300	1.05	1.0
Tol 9	NOT	06/04/26	IAC-24	3×900	1.85	IAC-36	3×300	2.00	0.9
Tol 1457-262a	NOT	04/03/20	IAC-20	3×300	1.80	IAC-19	3×300	1.85	1.0
Arp 252	NOT	04/01/20	IAC-39	4×300	1.52	IAC-36	3×300	1.55	0.7

[a] The worst value for the seeing is indicated.
[b] Images from Méndez & Esteban (2000).

λ6562.82 emission line taking into account the recession velocity of the object given by the NASA/IPAC Extragalactic Database (NED) and/or our optical spectra. We obtained Hα images for all galaxies in our sample apart from POX 4 and NGC 5253, for which we used the results provided by Méndez (1999) and Meurer et al. (2006), respectively. Table 4 compiles all the data (date, telescope, filters, exposure time, airmasses, and worst seeing) concerning our Hα observations. The quality of these observations is remarkable: the worst seeing of the Hα images for 9 up to 19 (47 %) of the galaxies is lower than 1$''$. The details of the reduction process and analysis of the Hα images are described in Appendix C.

2.5. Stellar populations

For all galaxies and knots, we compared our optical/NIR colors (corrected for extinction and emission of the ionized gas) with the predictions given by three different population synthesis models, STARBURST99 (Leitherer et al. 1999), PEGASE.2 (Fioc & Rocca-Volmerange 1997), and Bruzual & Charlot (2003), to estimate the age of the dominant stellar population of the galaxies, the star-forming regions, and the underlying stellar component. We selected these models because while, the first are based on Geneva tracks, the other two use Padua isochrones (Bertelli et al. 1994) in which thermally pulsing asymptotic giant branch (TP-AGB) phases are included. We assumed an instantaneous burst with a Salpeter IMF, a total mass of 10^6 $M_\odot$, and a metallicity of $Z/Z_\odot$ = 0.2, 0.4 and 1 (chosen in function of the oxygen abundance of the galaxy derived from our spectroscopic data, see Paper II) for all models. Since these models are optimized to study the youngest stellar populations within the galaxies, ages above 500 Myr cannot be measured reliably, but their values are useful for discriminating between young ($\leq$25 Myr), intermediate (100–300 Myr), and old (>500 Myr) stellar populations (see López-Sánchez, Esteban & García-Rojas (2006) for details of the method). We used the W(Hα) of all analyzed star-forming knots to estimate the age of their most recent starbursting episode comparing with the predictions given by the STARBURST99 (Leitherer et al. 1999) models (last column in Table 7), which have a far smaller error (between 0.1 and 0.5 Myr) than the ages derived using broad-band colors (typically, between 2 and 5 Myr for young stellar populations). In Paper II we will show that the ages derived from W(Hα) are in good agreement with those derived from the spectroscopic data. As we conclude in Sect. 4 and Paper III, a proper estimate of the stellar population age for this type of galaxy using broad-band filters is only obtained when bursts and underlying components are independently considered.

3. Results

CHECK the full paper in the A&A webpage:
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6361:200809409
or in the personal webpage of the PI:
http://www.atnf.csiro.au/people/Angel.Lopez-Sanchez/pape
False color pictures of the galaxies can be found in:
http://www.atnf.csiro.au/people/Angel.Lopez-Sanchez/pictu

4. Summary

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5. Appendices

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